available pin array, and so that the individual Braille cells displayed can be clearly distinguished from the neighboring cells.

The driving algorithm to be used for the extended array tactile graphic display or this invention must consider conversion of images to the tactile domain. Tactile graphic images have significant differences from visual graphic images, because the sense of touch uses different methods from the sense of sight to detect, identify, and organize object features. The greatest priority for a tactile graphic display is to allow the identification of distinctive features such as lines, curves, and borders between regions, and to provided differentiation between different regions by means of tactile cues such as textures.

The first step in tactile display of a visually oriented image is to convert it to a format that displays well on the tactile display. Conversion of visual cues may include the use of varying line widths to convey emphasis. If the tactile display uses vector drawing to set the pins, then part of this conversion implements a way to efficiently express the desired image in terms of vectors.

The extended tactile graphic array is constrained to place the stimulus points at the physical locations of the pins **21** that make up the array. If the image to be displayed has features that are not exactly aligned with the pin array, then the driving algorithm must determine how these features are to be displayed. An example of such a decision is to offset the displayed features slightly to align them with the pins in the display array. Display of diagonal lines offers the choice of setting only those pins that fall exactly on the desired line (which may leave many gaps in the line and produce a result that is difficult to interpret as a line), or setting a sufficient number of pins to produce the perception of a continuous line, which may result in a slightly jagged (stair step) line that is of varying apparent width depending on the angle of the line relative to the layout of the pin array. These issues do not interfere with the production of usable tactile graphic images, however, and the effects can be reduced as advances in the technology permit design of the display with closer pin spacing.

If the tactile graphic array does not use a regular pin pattern (e.g., using instead an array which includes dots spaced for the display of Standard Braille), then the driving algorithm must take into account the physical locations of these pins in the array, unless the pins are set by vector drawing, in which case the driving algorithm is less sensitive to the physical pin layout.

As may be appreciated from the foregoing, apparatus and methods in accord with this invention provide new refreshable tactile graphics display technology and design concepts for implementation and use of extended tactile graphic arrays. For an extended tactile graphic array with thousands of pins, major cost saving can be achieved by using each actuator to drive multiple pins via a scanning process. A high-speed repetitive scan that continually refreshes all the pins is conceivable, and may provide benefits for the depiction of moving pictures, but the most cost effective approach at present is one in which a slower scan is used and the pins are retained in place when not being driven by the actuators. The pins are therefore set into place by the operation of the actuators, remain in place as they are read, and are later reset to a default position. The number of actuators needed can be reduced by a factor of hundreds or more compared to the conventional approach of one actuator per pin. It is possible utilizing the foregoing to provide a practical implementation in which an extended tactile graphic array is driven using only a single actuator.

The primary intended application for the apparatus and method of this invention is a computer driven refreshable tactile graphic array for the display of tactile images for blind and visually impaired users. The technology encompasses both two-level display (each pin either extended or not extended), and multi-level systems for the display of relief images. The display of Braille text (of either standard or non-standard dimensions) is an important additional function of this technology, and an alternate implementation with pin spacing for Braille can be optimized for Braille, with graphics as a secondary function. Implementation options include a display screen (or matrix) that can be removed while retaining the written tactile graphic image, a very low cost screen that is written directly by the user rather than by computer-controlled actuators, and a display that can also create permanent hardcopies of the displayed image.

What is claimed is:

1. An extended refreshable tactile graphic array apparatus for tactile display comprising:

a display surface having a pin array of at least hundreds of movable pins maintained thereat, said display surface configured so that pins in said pin array are retained at a selected extension above said display surface after an applied force is utilized to move said pins;

pin retention means configured for resisting forces applied during sensing of said display that are greater than said applied force; and

actuating means to apply said applied force for selectively moving pins in said pin array between at least first and second positions, a single actuator of said actuating means for moving multiple said pins in said pin array.

2. The apparatus of claim **1** wherein said actuating means includes a selected number of said single actuators to as few as one said single actuator, and wherein said pin retention means includes a movable locking sheet for maintaining establishment of positions of all said pins in said pin array without continued influence by said actuating means as a user senses the tactile display.

3. The apparatus of claim **1** wherein said pin array is configured in one of a rectangular pin array, a staggered pin array, and an array with pin spacing that includes a pattern configured for display of standard or nearstandard dimension Braille text so that said apparatus supports display of both standard or near-standard dimension Braille text and high resolution tactile graphics.

4. The apparatus of claim **1** wherein said actuating means includes a vector drawing mechanism in which said single actuator can be moved along specified vectors for selected movement of any of said pins to generate a tactile graphic image for the entire said pin array.

5. The apparatus of claim **1** wherein said pins include enlarged heads at one end of a shaft and surface features at said shaft cooperative with said pin retention means to enable control of pin position, and wherein said surface features are sufficient to allow each of pins to be moved to a selected one of a plurality of elevations with said enlarged heads a selected distance above said display surface.

6. The apparatus of claim **1** further comprising means for moving all of said pins to a default position.

7. The apparatus of claim **1** wherein said display surface and said pin retention means are mounted together in a stacked matrix, said stacked matrix detachable from said apparatus with a tactile graphic image displayed thereat maintained, whereby a user can use said actuating means